IMPACT OF A SECOND FIREHOUSE ON RESPONSE TIME

STRATEGIC MANAGEMENT OF CHANGE

BY: Robert G. Taylor
Morristown Fire Bureau
Morristown, New Jersey

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ABSTRACT

This research project explored the effects that building a new firehouse would have upon emergency response times to past fires, target hazards and equal coverage concerns in Morristown, New Jersey.

The problem that was addressed was that, with all fire suppression forces deployed from one location, longer response times were being experienced in a large area, which included several significant target hazards

The purpose of this research project was to explore the feasibility of continuing to protect the entire town from one firehouse, and to study the effects of constructing a new firehouse on the southeast side of town.

Descriptive research was used to study the patterns of town's fire problem, geography and response characteristics. Evaluative research was used to analyze the feasibility of the present practice of maintaining all forces in one location by measuring the effects of a new southeast firehouse upon emergency response distance and travel time.

The research questions posed were:

1. How are life safety and fire loss affected by response time?
2. Are there nationally recognized standards for response time?

3. How have response times been affected by the closing of the Market Street firehouse and moving all companies to Speedwell Avenue?
4. How would the building of a new firehouse on the southeast side of Morristown impact life response time, life safety, and fire loss?

The procedure began with a literature review of deployment analysis, response time and distance, and their relation to life safety and fire loss. The deployment considerations of risk, hazard and equal coverage were examined. Response distances were measured to past fires and target hazards. Measures of equality of service were performed.

It was found that a second firehouse would shorten travel times, enhance life safety, and lessen fire damage. Recommendations included continued efforts to plan for a new firehouse and continued research.

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INTRODUCTION

The Town of Morristown, New Jersey was settled in 1710 and incorporated in 1743, and grew around a central block-sized park, known as The Green. The main streets radiate outward from the Green like spokes of a wheel. Morristown's original two staffed firehouses were built soon after the Civil War just off opposite sides of The Green, on Market Street and on Speedwell Avenue. These firehouses were only about 300 yards apart, as was appropriate when almost all of the value of the town was located on or near the Green. In 1971 the Speedwell Avenue companies were relocated to a newly built firehouse further out on Speedwell Avenue, almost one half mile from the Green.

In December 1996, the 125 year old Market Street firehouse was closed after an inspection by an architectural engineering firm which revealed several deficiencies ranging from substandard electrical wiring and gas lines to stress on the bay floors. Market Street's two engines were moved into the Speedwell Avenue firehouse, and all initially responding apparatus and personnel were then located together on the north side of town.

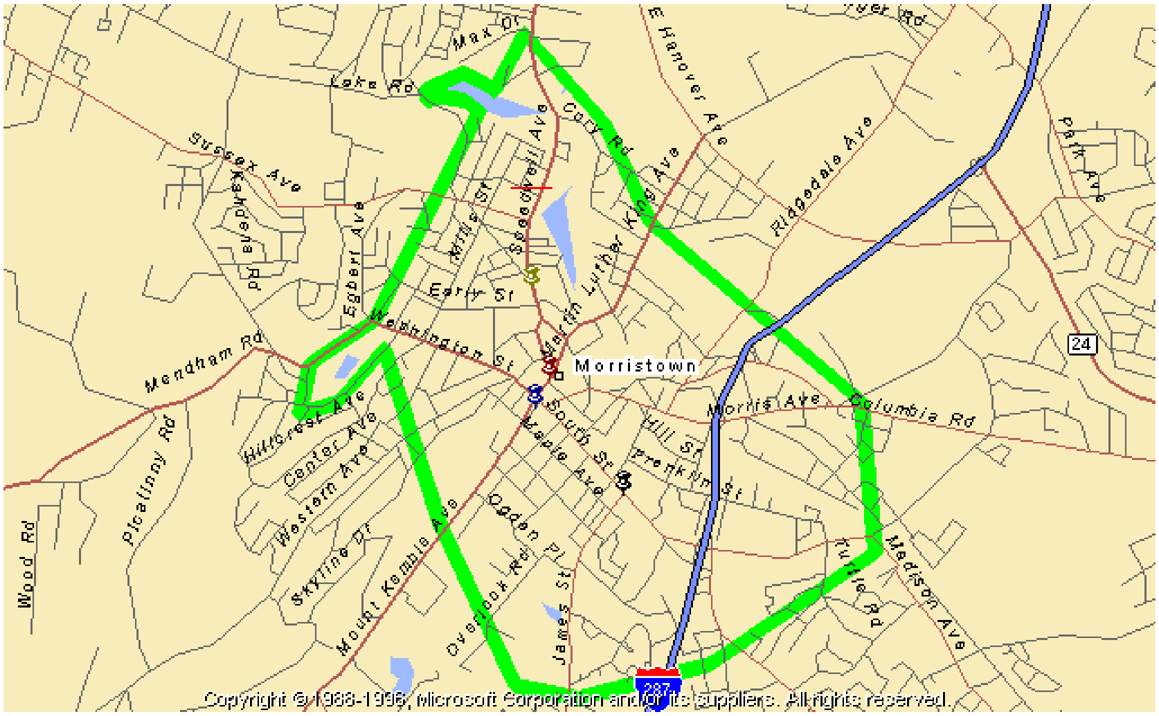


Figure 1 - Morristown staffed firehouses, shown as pins on map, from top: Current Speedwell Avenue firehouse (yellow pin); closed former Speedwell Ave. firehouse (red pin); recently closed Market Street firehouse (blue pin); proposed firehouse location area near South and James Streets (black pin).

The problem prompting this research project was that, with all fire suppression forces deployed on the north side of The Green, longer response times were being experienced to a large area in the southeast side of Morristown, which included several significant target hazards. The town needed a method of evaluating data for present and future deployment decisions, including the question of whether to build a new firehouse.

The purpose of this research project was to explore the feasibility of protecting the entire town from one firehouse, and to study the effects of constructing a new firehouse on the southeast side.

This study makes use of descriptive research, which brings clarity to the patterns of town's fire problem, geography and response characteristics. Additionally, evaluative research was used to analyze the feasibility of the present practice of maintaining all forces in the northeast side of the town by measuring the effects of a new southeast firehouse upon emergency response distance and travel time.

The research questions examined were:

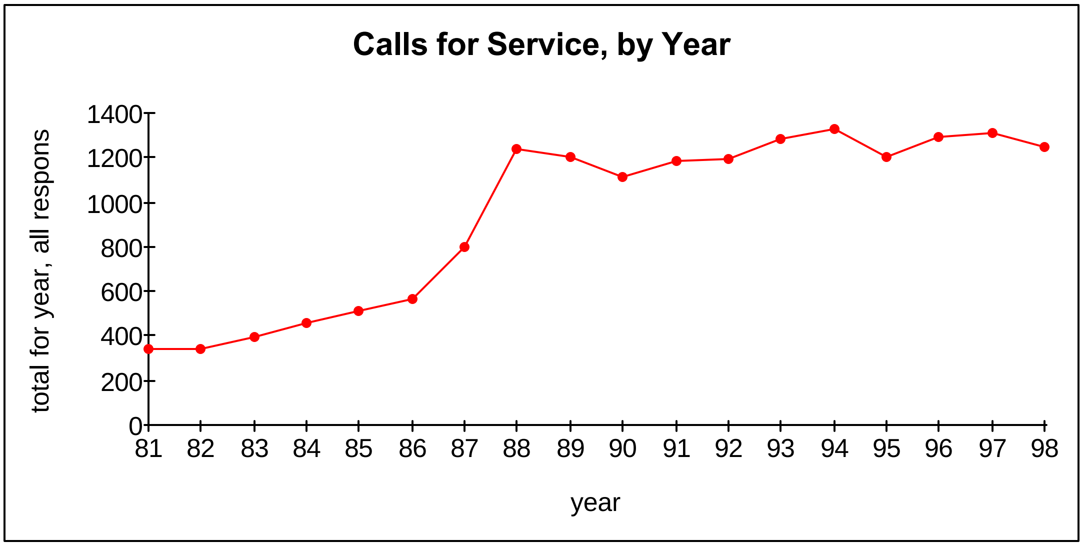
1. How are life safety and fire loss affected by response time?
2. Are there nationally recognized standards for response time?
3. How have response times been affected by the closing of the Market Street firehouse and moving all companies to Speedwell Avenue?
4. How would the building of a new firehouse on the southeast side of Morristown impact life response time, life safety, and fire loss?

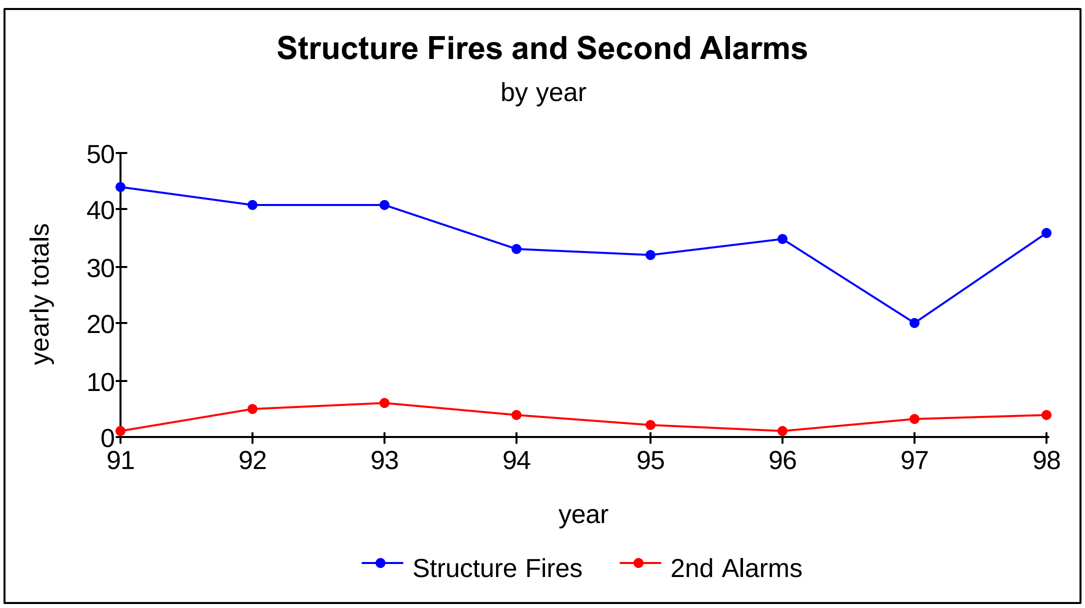
BACKGROUND AND SIGNIFICANCE

Morristown, New Jersey is a small city/large town of 17,000 residents and 100,000 daily transients. The 1990 census reported 14,633 households with a 1989 median income of $59,413 and $2,448,515,000 aggregate worth of owner-occupied residences (U. S. Census Bureau, 1997). Commercial occupancies include four hi-rise office buildings and one hi-rise hotel. Morristown houses the county seat and jail complex. Morristown's Fire Bureau protects Morristown Memorial Hospital, the regional trauma center, and Morristown Airport, which is the third busiest airport in the state. Finally, there are several buildings of irreplaceable historic value, such as the Ford Mansion, which was Washington's headquarters for two years during the Revolutionary War.

Morristown has a history of strong volunteer fire service. Two hundred years ago, in 1797, a society was organized for the use of buckets, fire hooks, and cisterns. By 1837 the Morristown Fire Association was created by act of legislature and empowered to support two fire companies by special taxation. The six volunteer companies that are in service today were formed between 1867 and 1889. Full time career firefighters were first hired in 1929.

Today Morristown is served by about 20 active volunteers qualified for interior structural firefighting, and an additional 30 in support capacity. The career firefighters, presently numbering 29 divided into four platoons, are no longer merely driver/operators, but generally function as one company at an alarm until volunteers arrive. During the 1990’s call volume has remained relatively constant at around 1200 calls per year.





In 1997 the Morristown Fire Bureau responded to 1310 alarms, which included 20 structure fires.

After the Market Street firehouse was declared unusable in 1996, the Long-Range Firehouse-Needs Committee was formed by the Mayor, consisting of the Fire Chief, the Business Administrator, representatives of the career and volunteer firefighters, and local business and political leaders. The Committee decided that the Market Street location, which was a “narrow, congested, one-way street with a terminus into the notoriously congested one-way rotary traffic at the Morristown Green” was no longer appropriate (Morristown Long-Range Firehouse-Needs Committee, 1997, p. 3). The Committee recommended building a new firehouse on the southeastern part of town, and identified and evaluated four possible sites: a parking lot at Franklin and Elm Streets; the Town Hall parking lot between South and Franklin Streets; 214 South Street; and a vacant garage on Maple Avenue and Catherine Lane.

This paper has been produced to satisfy the applied research project requirement for the Strategic Management of Change course at the National Fire Academy. The project relates to the course work on Phase 1 (Analysis) of the Change Management Model, especially those sections presenting analyzing the existing situation; performing a needs assessment; identifying influences creating a need for change; quality of service; transitional change; and informational techniques to promote change.

Finally, this research will clarify and quantify some issues which will enable the Town of

Morristown to make sound decisions in suppression resource deployment.

LITERATURE REVIEW

Modern fire resource deployment analysis began as part of the late 1960's Great Society drive to improve the quality of life by federal programs and funding. In 1973, after two years of research, the Report of The National Commission on Fire Prevention and Control (America Burning) was released. Its findings and recommendations generated a national drive to address America's fire problem, including funding of new college and university research and courses of study, textbooks, new apparatus, tools, and improved protective gear for firefighters. In this climate, and with recently developed computer hardware and software, groups such as the Rand Corporation began to apply principles of operations research to fire service problems, resulting in resource deployment analysis. "Deployment analysis is the application of systems analysis to the problems of deploying (or allocating) firefighting resources. We use systems analysis to help make better deployment decisions because, in many cases, it provides an objective framework for comparing alternative policies" (Walker, 1979, p. 69). Although these sources date from the mid 1970's, they are foundational and will be used extensively in this study.

In many jurisdictions, the number and locations of fire companies that exist today represent obsolete historical decisions. Examples include: where volunteer companies were first organized (The Department of Housing and Urban Development [HUD], 1977, p. v); “Intuition and judgment, donated property, a generalized objective of being placed on or near main thoroughfares, within jurisdictional boundaries, and in an area far from existing stations” (Springer, 1995, p. 34); the distances men or horses could run; the spacing required by the requirements of the Standard Grading Schedule of the National Board of Fire Underwriters and its successor, the Insurance Services Office of the American Insurance Association (HUD, p. 35; Rider, 1979, p. 323); as part of the small town Town Hall complex (Buxton, 1994, p. 1); and, on a hill top to make it easier for the horses to attain speed Billington, 1995, p. 7). Modern decisions are usually based on distance between stations, population served, and hazards to districts (Billington, 1995, p. 11). Gay and Siegel conclude: “Thus, stations are spread throughout a community and sometimes located near major high risk facilities” (1987, p. 1).

One important consideration of fire station siting has always been response time, or the time between alarm and suppression when units are responding to the scene of an emergency. Hostile fire has long been recognized to be a progressive threat, against which too little or too late intervention both produce the same disastrous result. “Response time to fire calls is critical to the outcome of the emergency” (City of Lodi (Cal.) Fire Department, 1989, p. 3).

Response Time and Life Safety

Response time impacts upon life safety (including firefighters' life safety), as well as damage and loss due to fire. Barr and Caputo (1997) state:

> Nothing is more important than the element of time when an emergency is reported. Fire growth can expand at a rate of many times its volume per minute. Time is the critical factor for the rescue of occupants and the application of extinguishing agent" (p. 10-250).

The longer the fire building burns unchecked during response time, the greater the fire problem and threat. Firefighters are definitely stakeholders in addressing response time. "When determining acceptable response times, consideration must be given to flashover and building collapse as they relate to occupant and firefighter safety" (Vadnais, 1990, p. 4). Chief Vadnais also found that benefits of lower response times included "lower workman compensation claims as the result of lowered stress and smaller scale fires due to the faster response" (p. 6). Shortened response times also benefit the community indirectly, as reported by Chief Reed: "Improved service delivery [from faster response] improves firefighter safety, fire dollar loss of property, reduces insurance premiums, and increases the opportunity for rescue" (1992, p. 16).

Response Time and Fire Damage and Loss

Although that it is evident that there is a direct relationship between response time and loss, it is difficult to define the exact relationship. At the 1980 Annual Meeting of the NFPA, fire protection engineer Martin Holba reported on a study of the relationship between response time and damage involving 115,000 structural fires in New York City. He found that "One minute of response time was estimated to be worth from $100 to $10,000 in damages or loss. By comparison, a similar study made in Great Britain in 1973 indicated these response-time costs to be about $125 to $250 for dwellings and approximately $2,500 for industrial-commercial properties" (p. 37).

In one case Wilson (1994) found that "An extra 60 seconds of response time would have increased the resulting damage from about US $150, with the ability to sleep there that night—to over US$40,000, with loss of personal treasures and no sleep there for months" (p. 5).

John Granito and John Dionne, writing for the International City Management Association, related response time to effectiveness: "To account for various response times, you could project a reduction in effectiveness of 50 percent for each minute or increased response time. Therefore, a three-minute response is only 25 percent as effective as a response of one minute or less (1988, p. 113).

Response Time as a Proxy Measure of Fire Department Success

Jack Hauser of the New York City Rand Institute, in a study of the travel characteristics of emergency service vehicles prepared for the Department of Housing and Urban Development [HUD], observed:

> One of the most important indicators of the performance of any emergency service is response time....Since response time can have a significant impact on the loss of life and property at an emergency, it is used as a principal measure of effectiveness in many models developed for analyzing the deployment of emergency vehicles. (1975, p. 1)

HUD (1977, p. 4) explains:

> Although there is agreement on the primary objectives of the fire department--to minimize the loss of life and property caused by fire--fire deployment analysts are not able to base their studies directly on these objectives, because there are no reliable methods for estimating the effect of changes in deployment policies on the objectives. For example, if the number of fire companies on duty is doubled, or halved, no one can state with any degree of certainty what will happen to fire deaths or to the amount of property that is destroyed by fire. To analyze deployment policies, then, we must use proxy measures of performance.

HUD also identified two groups of these proxy measures: those dealing with insurance concerns, and those affecting Response Time. Billington (1995) concludes:

> In measuring effectiveness of fire departments response time has often been used as a measurement because it is widely believed that the faster the response, the lower the loss, which contributes to citizens' perceptions of the responsiveness of their government, and a feeling of security. (p. 8)

Response Time Components

Chief Gary McCarraher observed, "Contrary to casual thought of how quickly vehicles can reach an emergency, response time is a complex measurement of several identifiable time segments" (1992, p. 6). Different sources use slightly different models and nomenclature. Making the situation even more confusing, the progress of a fire from ignition to extinguishment is also described and defined differently by different authors. Vadnais (1990, p. 2) defined response time broadly, as "the total elapsed time from ignition to suppression". Walker (1979) defined response time as "The length of time from the moment the fire department is notified until a fire company is on the scene and ready to operate"(p. 82), which included the component intervals of dispatching time, turnout time, and travel time listed by Hausner (1975). HUD (1977, p. 6) added setup time (also known as assault time by Strang (no date, p. 7)) as part of response time. Barr and Caputo (1997) further subdivide setup time and add the component access time (i. e., the time required after arrival to move from the apparatus to the emergency). For Phoenix, however, response time stops when the first unit arrives on the scene

(Brewster, 1994). In the most detailed model, Rexford Wilson (1994) identified nine time periods over the course of a fire: free burn, permitted burn, notification, alarm processing, turnout, travel, setup, combat, and overhaul. These time periods are separated by ten benchmark points in time: ignition point, recognition point, detection point, alarm point, alert point, get-out point, arrival point, agent application point, flameout point, and extinguishment point.

Travel Time

When considering the problem of fire station locations, the travel time component is of special interest. Travel time, defined as "The length of time between the start of the unit's trip and its arrival at the scene" HUD (1977, p. 6); and as "The amount of time from wheel start to wheel stop" by Barr and Caputo 1997 (p. 10-250). Travel time is "the only component of response time that is affected by changes in the deployment of fire companies" (Walker, 1979, p. 82). Thomas Holland adds "Response time/travel distance measurement is the one unknown factor that we have the greatest ability to change. Therefore it is considered to be a major factor in the planning process of fire station locations within the community"(1993, p. 38). "Fire stations and other fire protection facilities are placed in a community on the basis of risk analysis and response time requirements (Requate, 1993, p. 5). Allen Clark notes that time lost in other components of response time (due to delayed alarm, dispatch time, or turnout time) cannot be made up by driving at excessive speeds or by taking other needless risks en rout (1986, p. 29). Studies in New York and Denver found that Travel Time accounts for about 50% of the total response time for the first due company, and an even larger fraction for later arriving companies (Kolesar, 1979, p. 161).

Response Time Benchmarks

Some authors, e.g., Granito and Dionne, (1988) use “response time” to describe the interval defined above as “travel time.” This presents difficulty in comparing measures of time between studies.

This review of the literature did not discover any current nationally recognized standards specifying acceptable response time parameters. “Unfortunately, the fire service has developed no data which can be used to determine exactly what constitutes a reasonable response time” (Holba, 1979, p. 10). This appears true even today. Dr. Glenn Martin, a national research consultant on computer aided dispatch systems, stated (in 1994) that there were no nationally recognized response standards established for the fire service (Hardiman, 1994, p. 10). Granito and Dionne suggest: “In some urban areas, one and a half minutes are considered a desirable maximum, whereas in other urban areas the number is set at two and a half or three” (1988, p. 120).

However, as reported by Chief Billington (1995, p. 8), the NFPA presented criteria for both response distance and response time in 1972. The criteria were to have 90% of the responses receiving on scene condition reports within three minutes (first due), and the entire first due assignment on scene within five minutes. Response distance limits in built-up areas were one and one-half miles first due area and three miles for the rest of the assignment.

Some published goals of fire departments around the country include:

- Austin Fire Department has set an average response time goal of 30 seconds “scramble” (or turnout) time and 3 minutes drive time for the first fire apparatus to arrive at the scene of the emergency (Sybesma, 1995, p. 56).

- “The Wichita Fire Department has had the goal of placing a piece of emergency apparatus at any emergency scene, on the average, in less than four minutes from the time the citizen calls for assistance” (Austin, 1994, p. ii).

- In Edmonds, Washington the Fire Department set an on scene goal of 80% of fire calls in less than 9 minutes (includes turnout and travel time); the actual average achieved in 1994 was 1:03 turnout and 3:49 travel for total of 4:52 (Springer, 1995, p. 26,7).

- In a study of 15 municipalities in Texas, Metzger (1994) found that the average response time of all of the survey participants was calculated for the first due companies at 3.9 minutes.

- Lodi, California has stated this response goal: “The amount of area within the current city limits which is outside of the present three minute driving time should be reduced to as near zero as possible, and no area should exceed four minutes driving time” (City of Lodi, 1989, p. 5).

- Phoenix, Arizona maintained a "target response time," which included turnout and travel time, of 3 minutes (Mason, 1996, p. 9).

Flashover

Discussion for using response time as a criterion can be associated with the fire phenomena of flashover (a transition from a growing fire to a fully developed fire where all combustibles in a room become involved) which occurs in six (6) to nine (9) minutes" (Billington, 1995, p. 7). According to the International City Management Association (ICMA), a primary fire department objective should be to arrive at the scene of a fire prior to flashover (Granito and Dionne, 1988, p. 120). Stanley Crosley, Fire Chief in Sidney, Ohio explains:

> One of our objectives, as a fire department, is to try to arrive at the scene prior to flashover...Flashover is a critical stage of fire growth for two reasons. First, no living thing in the room will survive [and] the chances of saving lives drops dramatically. Second, flashover creates a quantum jump in the rate of combustion, and a significantly greater amount of water is needed..." (1994, p. 17)

Furthermore, in tests reported by Hartzell for the NFPA (1986, p. 4-38), rooms remote from the flashover room were found to contain debilitating and lethal amounts of CO within two minutes after flashover.

The exact time to flashover depends on many unknown variables. The following estimates were found in the literature:

- The Phoenix Fire Department (1993) and ICMA (Granito and Dionne, 1988) found that flashover can be expected at seven minutes after ignition.

- "Research indicates that a room fire can progress from ignition to flashover (simultaneous ignition of all contents) in six to nine minutes" (Gay and Siegel, 1987, p. 3).

- "Fire experience and full scale experimental fires have shown certain materials capable of producing room flashovers in as little as fire minutes from the start of flaming" (Vadnais, 1990, p. 4).

- "Flashover occurs between four and ten minutes in the build up of fire" Meyers, 1994, p. 6).

Travel Distance

In addition to time related aspects of response, the literature also considers distance. “Above all else, travel time depends on the distance the apparatus must go...There is a long-standing precedent for the direct use of distances. The ISO grading of municipal fire departments is based on distance standards” (Kolesar, 1979, p. 161). Holba (1980, p. 35) summarizes the distance of the older Insurance Services Office (ISO) standard, the 1974 Municipal Grading Schedule: “ISO’s maximum requirements dictate a three-quarter-mile response for an engine company, and a one-mile response for a ladder company.” In 1980 The ISO introduced the Fire Suppression Rating Schedule, which also specifies distance standards: ”The formula for fire department credit includes a review of company distribution, which requires an engine company within 1 1/2 miles of every build-up area of th4e city and a ladder/service company within 2 1/2 miles of every build-up area of the city” (Coggan, 1995, p. 195). As reported by Holland (1991, p. G-23), Goswick (1991, p. 4) and Meyers (1994, p. 4), the NFPA recommended that a first due engine company be located within 2 miles of residential areas, one and one-half miles of commercial areas, and within one mile of buildings that require a 5,000 gallon per minute fire flow. This recommendation was written by Gordon McChinnon in the 14th edition of the Fire Protection Handbook (1976), but not included in the 15th or subsequent editions. Writing for the Fire Chief’s Handbook in 1995, de Silva states: “Generally a target for response distance should be set in accordance with practical department experience and accepted standards:

-Commercial areas: one mile

-Residential areas: two miles

-Low-density areas: three miles" (p. 478).

Sybesma (1995) reports a distance standard of the 1991 criteria of Texas State Board of Insurance: "Every structure should have a station within 1.5 miles as the crow flies" (p. 55).

Relating Response Distance to Response Time

Having in mind the importance of response time, and travel time in particular, the literature search turned to the problem of how travel time has been found to be related to travel distance. In 1977 HUD suggested:

> There are many ways to estimate travel times [from travel distance]. For example, the travel distances between firehouses and incident locations in a region could be clocked on an odometer or measured on a map; these distances could be translated into travel times by timing actual trips or assuming a constant travel speed. (p. 14)

Another method of relating time and distance is to simulate response and measure time and distance (Landolfi, 1997, p. 10).

Some estimates of average emergency response speeds found in the literature are:

- 30 mph (Thompson, 1998, p. 13);

- from 19 mph on short, downtown streets to 36 mph on long, non-residential, multiple-lane streets (Fitzpatrick, 1989, p. 5);
- 20 mph, average urban response speed (Granito and Dionne, 1988, p. 120);
- 20 to 24 mph for an engine and 17 to 20 mph for a truck (Wilson, 1994, p. 19);
- 26 mph, average safe response speed (Lodi Fire Department, 1989, p. A5);
- 30 mph (Sybesma, 1995, p. 56).

The Rand-HUD studies developed and tested an equation which relates response time to response distance (Walker, 1979, p. 377):

> A city may obtain useful travel-time estimates by using [the following equation], which is based upon experimental results in Trenton, Denver, Wilmington, and Yonkers:
>
> $T = 2.10 \sqrt{D}$ when D is less than or equal to 0.38 mile;
>
> or: $0.65 + 1.70\,D$ when D is greater than or equal to 0.38 mile.
>
> The constants of the function [2.10, 0.38, 0.65 and 1.70] can be estimated for a specific city by collecting data on the responses of fire companies over a period of time. However, as a result of collecting such data in several cities, we have found, surprisingly, that the values of these parameters vary little from city to city or by time of day. (HUD, 1977, p. 17)

An early New York City study (Kolesar and Walker, 1974, p. v) which involved measuring over 2000 responses found the same result:

> Travel time increases with the square root of distance for short runs, and linearly for long runs. Although average response velocities vary somewhat by time of day, the variations are smaller than expected and can be ignored for many planning purposes. There are only small variations in the parameters of the function relating travel time to travel distance in different regions of the City. As a result, a single continuous function can adequately represent the relationship between travel time and travel distance at all times of day in all parts of the City. This function is a square-root relationship for response distances up to some point d, and linear for response distances greater than d.

In a Yonkers, New York study, Swersey (1979, p. 559) found similar results:

> The response data were also analyzed to determine what effect the time of day had on response speed and hence, on travel time. It was found that a time-of-day effect did exist, but that it was less significant than expected. There were no apparent practical differences in travel speed between daylight hours and nighttime hours, or even between rush hours and nonrush hours.

However, in other locations, it was found that travel times may be up to 20 % longer during rush hours (Kolesar, 1979, p. 158).

Average Travel Distance

Calculation of a statistical average travel distance in a region provides a valuable measure to determine level of service, to compare service in different parts of city, and to analyze the effects of different deployment decisions.

The HUD studies (1979, p. 15) stated:

The simple relationship that has been found to give good estimates of average travel distance is called the square-root law:

$$D = c \times \sqrt{A/N}$$

the square root law states that the average travel distance [D] is equal to a constant[c] times the square root of the area [A] divided by the number of companies [N] available.

In other words "[Travel] distance increases in proportion to the square root of the area, and it decreases in inverse proportion to the square root of the number of engines"(HUD, 1977, p. 15).

Kolesar and Blum explain:

Inherently, the square root law follows from dimensional analysis: distance is the square root of area, and the area served from each fire house is inversely proportional to the density of fire stations. Thus it seems plausible that the expected fire company response distance should be inversely proportional to the square root of the density (number per

> square mile) of firehouses. (1973, p. 1369)

Kolesar and Blum further state:

> It [square root law] states that the average response distance in a region is inversely proportional to the square root of the number of locations from which emergency service units are available to respond. The principal result, when combined with a response time-response distance function, enables one to predict expected (average) response times in a region... (1973, p. 1368)

Good approximations for the constant [c] are known. "From studies in several cities, the constant [c] for the first-arriving engine company has been found to be approximately equal to 0.6., and... for the second-arriving...approximately 1.0." (HUD, 1977, p. 15). The significance of the square-root law is summed up by Kolesar:

> First the model is very simple. It links travel distances to the key decisions variable--the number of companies in a region--via an equation that can literally be used to calculate results on the back of an envelope. Second, the model is justified by mathematical analysis...Third, the model has been tested and verified empirically. (1979, p. 178)

Although these studies date to the 1970's, their findings have been found to have continuous validity. Writing for the International City Management Association, Forsman found in study of Ames, Iowa that "The Rand travel time prediction formula was verified though analysis of actual run times. The Rand formula proved to be extremely accurate in predicting average travel time” (1988, p. 184).

Deployment Policy Considerations

Even with adequate tools to assess response times and response distances, the fire service planner faces formidable problems in finding the best arrangement of fire stations. HUD summarizes some of the conflicting objectives:

> A fire department would like to be able to concentrate its companies in the areas of greatest demand. However, the department must also provide a reasonable level of service to the lower demand areas....One objective of the fire department might be to minimize the total travel time to all fires that occur in the city. In this case, the companies should be placed close to where the fires are expected to occur....[but] Residents in the low-demand region might claim that they are receiving substandard protection and are being penalized for being careful and having few fires. Minimizing travel times to actual fires also ignores the potentially high fire hazards or special dangers that may be present in the low-demand region, for example, hospitals, school, chemical storage areas, nursing homes, etc.
>
> An alternative objective is to locate the fire companies so that the average travel time to alarms is made equal in the two regions. Using this objective, the number of companies would be almost the same in both regions. This may seem to be a more

> equitable solution. But, as a result, the travel time to many fires in the high-incidence region will be increased to reduce those to the few fires of the low-incidence region. Moreover, the average travel time throughout the city will be larger than the minimum possible. Under this policy, therefore, total fire losses in the city would presumably be greater than under the minimum travel-time policy because many fires would be getting slower responses. (1977, p. 37)

In sorting out these conflicting objectives, the literature review focused on hazard, risk, and equal coverage.

Hazard, or potential demand, is defined here as “The extent to which injury, damage, or loss will occur if there is a fire that is not promptly extinguished at a particular place” (Rider, 1979, p. 342). “Potential demand is related to the chance that a fire in a region will escalate rapidly” (Rider, 1979, p. 324). Hazard is not synonymous with risk: “The hazard factor is independent of the alarm factor...The hazard factor measures the *rate* of escalation of an average fire in a region. It does not measure the chance that a fire will occur” (Rider, 1979, p. 345). Considering just hazard, “Regions with a higher potential demand require smaller average travel times if they are to receive the same coverage as regions with a low potential demand” (Rider, 1979, p. 343). Examples of high hazard might include properties where, if fire were to occur, a large loss of life would result, such as a school; or properties where, if fire were to occur, a large property loss would result, such as a town’s main shopping district. Note that these examples (if of fire resistant, sprinklered construction with no fire history) may be considered high hazard but low risk.

Risk, or realized demand, is a measure of how likely it is that a property will experience a fire. Past fire history and trends are good indicators of present risk. “Realized demand is related to the actual [present] workload in a region” (Rider, 1979, p. 324). Crosley (1994) notes “Fires are not distributed evenly throughout the community. Structural fires tend to cluster in particular areas” (p. 18). Rider also notes that “Risk to property and risk to life usually increase or decrease together” (1997, p. 345). Although risk does not measure “how bad the fire will get,” different levels of fire problems may have different risks. Rider explains:

> In measuring demand in a region, it would not be reasonable to treat false alarms, for example, as if they were as important as structural alarms (that is, alarm signaling structural fires). Two regions with identical alarm rates--one with a high false-alarm incidence, the other with a high structural-alarm incidence--would certainly pose different problems for a fire department. The amount of work to be done in the region with the high structural-alarm incidence, as well as the risk to life and property, would be much greater… and the linear relation between risk and travel time has been found to be a reasonable approximation.” (1979, p. 342-344)

A risk-centered policy will place more resources near fire-prone areas. “If we assume that the smaller the travel time to a fire, the smaller the damage, the department’s objective of minimizing fire damage might be achieved (approximately) by minimizing the total time to all fires that occur." (Walker, 1979, p. 77).

Equal coverage is an objective that seeks equalized service and response times throughout a city. It is a grass roots democratic ideal, often expressed when citizens are dissatisfied, as in Lodi, California: "Emergency medical service and fire protection service are not provided equally among the City's population with the unequal response times created by the locations of present fire stations" (Lodi Fire Department, 1989, p. 2). Equal coverage may also be seen expressed by Chief Metzger's (1994) recommendation: "For obvious reasons, fire stations should be located, as practical as possible, in the center of a district" (p. 11). This may not be the location that minimizes risk or hazard.

According to Walker, measures of equalized coverage may involve at least four different criteria:

1. The amount of effort used to sustain the service (equalization of input)
2. The amount of service accomplished (equalization of output)
3. The amount of service accomplished in relation to residential needs (equalization of outcome)
4. The amount of residential satisfaction with the service (equalization of citizen's perceptions). (Walker, 1979, p. 77)

Policy Objectives Conflicts

[14-10-252]: Barr and Caputo give examples of conflicts between policy objectives by posing these alternatives:

- High life hazard or high dollar value [hazard vs. risk]
- High incident areas vs. low incident areas [risk vs. equal coverage]
- High rate of incidents that require a high level of resources vs. low rate [high risk/high hazard vs. low risk/high hazard]

Rider explains the risk vs. equal coverage conflict:

> One possible objective is to minimize the total travel time to all fires in a city. An allocation meeting this objective would place many companies in regions of high fire incidence [risk]. The problem is that when a fire does occur in a low-demand region, it may take a very long tome for the fire companies to arrive. Another objective might be to provide an "equitable" distribution of companies by equalizing the average travel time in all regions [equal coverage], but this would tend to increase travel times and workloads in high-incidence areas." (1979, p. 324)

When planning a new fire house, one question is:

> Should it be put into an area of increasing fire risk? or...into a low-density area that currently has a low level of fire protection?… "The two conflicting objectives--minimizing average travel time to alarms and equalizing travel times--must somehow be

> balanced" (Rider, 1975, p. 1,4).

Another balance must sometimes be found between risk and hazard:

> A run-down residential area might have a large realized demand because of a high structural alarm rate [risk], but a moderate potential demand [hazard] because the buildings are all brick. An industrial area, on the other hand, might have a low alarm rate [risk] but a high potential demand [hazard]. (Rider, 1979, p. 324)

Finally, Walker (1979) explains the conflict between hazard and equal coverage:

> Fire companies provide insurance against major catastrophes and loss of life by being available and close-by should a fire occur. All locations must be covered, not only those with long histories of fires. There are certain places where fires may rarely occur (nursing homes, chemical plants, hospitals, and high-rise buildings, for example), but when one does, the resulting loss of life and property can be substantial. (p. 85)

Fire House Siting Considerations

"Because distances, and therefore travel time, are preset by fire station location, extensive research and long range planning are required" (Clark, 1986, p. 29). As indicated above, one of the primary considerations is response time/distance. De Silva (1995) states, "The first consideration is station location and response time is the most critical item in site selection" (p. 478). Billington (1995) in Corona, California also found response times to be the main factor in determining fire station location (p. 2). According to Gay and Siegel "The location of fire stations is based on the theory that a rapid response is essential to protecting life and property since fire spread is largely a function of time" (1987, p. 3). In a survey of thirty-three Florida fire departments, Thompson (1998) found that the siting criterion most frequently reported was the desire to improve response times (51%)(p. 11).

Another siting consideration which is important to this study is the effect of locating a fire house on a main street. The literature produced differing opinions:

DeSilva (1990) advises: "In order to avoid traffic congestion, choose a site on a side street right off the main road" (p. 32). Cricenti (1997) agrees:

> Often fire stations are located on major travel routes, based upon the thinking that the response time is the most efficient; this approach has some validity. But this also removes what may be very expensive real estate from the tax roles. An alternative approach is to locate the station on a secondary route, just off the major route, and utilize a signalized intersection. (p. 10-180)

Crosley also votes for the side street location: "One and two blocks off the thoroughfares which is ideal because it allows us a short travel distance to these thoroughfares with traffic control devices" (1994, p. 10).

On the other hand, there were several recommendations for siting fire houses on the main streets. Gallagher (1989) notes that "A fire station located on a side street has the additional disadvantages of decreased visibility and difficult accessibility for citizens… Major intersections are an advantage...[providing] quick access to all four points of the compass" (p. 34). In Mt. Lebanon, Pennsylvania, Donovan, Gay, and Neufeld (1990) concluded: "It is imperative that the fire station be located on a major thoroughfare, Washington Road, in the central section of the community" (p. i).

PROCEDURES

The research procedure for this project began with a literature search at the Learning Resource Center (LRC) at the National Emergency Training Center in March and July of 1998. Additional materials were supplied by The Rand Corporation, the Office of Policy Development and Research, Department of Housing and Urban Development (HUD), and the Operations Research Society of America. Additional information was gathered from the Lloyd George Sealy Library, John Jay College of Criminal Justice, City University of New York; and from the author's personal library.

The literature search focused on the determinants of effective fire station deployment, and in particular, response time to areas with a high incidence of fire and to areas with target hazards. Another important consideration was found to be the goal of equalized coverage across geographic areas. The concepts, methods and formulas needed to conduct a deployment analysis for a small city of Morristown's size were found to have been developed in the 1970's, and to remain valid today.

Definition of Terms

Extreme - The point in a Ward/District which is farthest away from the Speedwell firehouse.

Center - The approximate geographic center of a Ward/District.

Demand Zone - A sub-section of a town created in order to compare response time, alarm rate, and hazard level to other parts of the town.

Deployment Analysis - "The application of systems analysis to the problems of deploying (or allocating) firefighting resources (Walker, 1979, p. 69).

Equal Coverage - The principle that states that, to the extent possible, all citizens of a municipality should enjoy the same level of fire protection and service.

First Due - The emergency unit expected to arrive on the scene first; usually also the closest unit.

Hazard - Although used somewhat interchangeably with the term “risk” in other places, here hazard means “The extent to which injury, damage, or loss will occur if there is a fire…”(Rider, 1979, p. 342). Answers the question, “How bad can it get?”

Market - The Morristown firehouse on Market St., which was closed in 1996.

Response Time - The elapsed time between the receipt of a request for service and the arrival on scene. Includes travel time as one of its components.

Risk - The probability that fire will occur. Answers the question, “What are the chances of having a fire?”

2nd alarm - In Morristown, the second alarm or general alarm is requested when the first arriving unit determines that there is a significant fire. This becomes the alarm point for summoning the volunteers and sometimes mutual aid.

Signal 11/Structure Fire - From the National Fire Incident Reporting System (a national data base maintained by the U.S. Fire Administration): any hostile fire within a structure.

Speedwell - The existing staffed firehouse in Morristown, located on Speedwell Ave.

Target Hazard - Defined by the Morristown Long-Range Firehouse-Needs Committee as: “Buildings that, because of their size, construction features, contents, or occupancy would present challenges to a fire department if there were to be a delay in responding to a fire there.”

Travel Time - That part of Response Time which starts when the unit leaves quarters and ends when the unit arrives on the scene; “wheel start to wheel stop.”

Ward/District - One of 14 political divisions of Morristown (1/1, 1/2, 1/3, 1/4, 2/1, 2/2, 2/3, 3/, 3/2, 3/3, 4/1, 4/2, 4/3, and 4/4) used in this study as “Demand Zones.”

Research Methodology

The thrust of this project was to evaluate the impact of constructing a new firehouse on the southeastern side of Morristown. The first step was to divide the town into smaller sections or “demand regions” (Donovan, Gay, and Neufeld, 1990; Lewis, 1986). It was decided to use the Ward and District divisions created after the 1990 census as demand zones. Each of the 14 Districts (identified as W/D, e.g., “1/2” for Ward 1, District 2) contain approximately one-fifth of a square mile in area and a population of approximately 1,000 residents (figure 2).

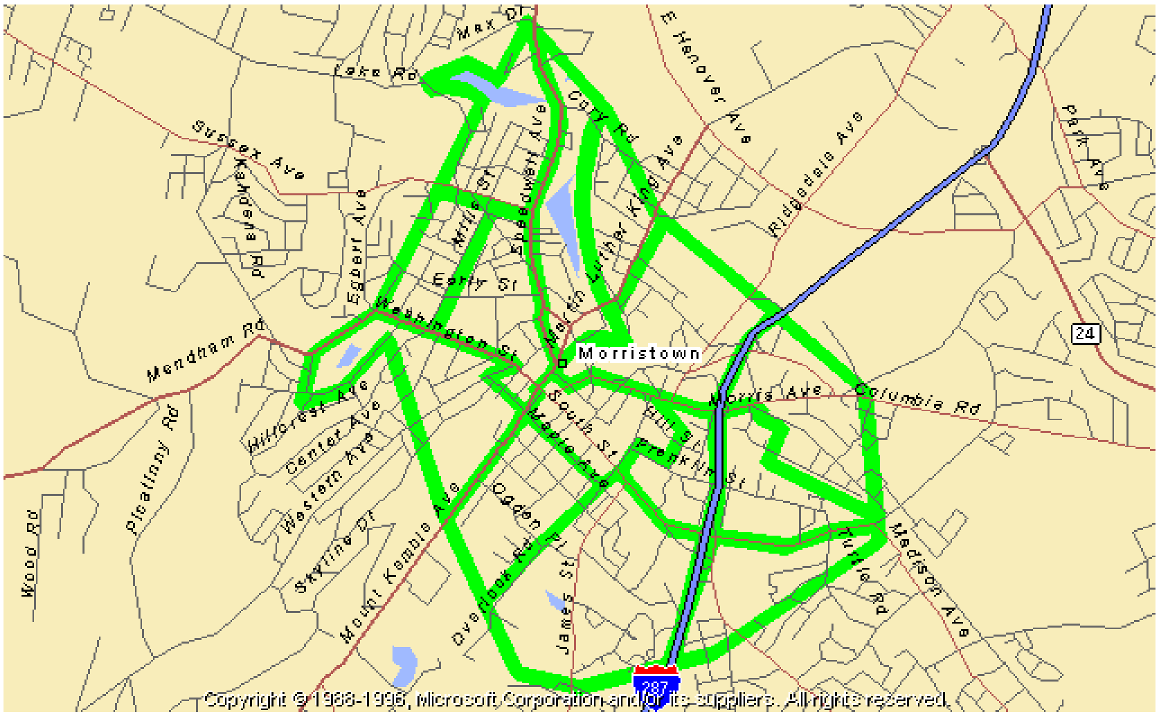


Figure 2 - Ward and District boundaries

For each of the 14 W/D's, an intersection or other identifiable feature was chosen to approximate the geographic center of the W/D, referred to as "Center." The point in each W/D having the longest driving distance from the existing firehouse (referred to as Speedwell) was also identified, referred to as "Extreme."

Morristown's Long-Range Firehouse-Needs Committee selected four possible sites for a new firehouse. All four were within 300 yards driving distance (250 yards as the crow flies) of the intersection of South and James Sts. This intersection was chosen as an approximation to represent the location of the new firehouse (referred to as "James") for all distance measurements.

Target hazards were identified by reviewing the list of registered Life Hazard Uses registered in Morristown by the Fire Official according to the New Jersey Uniform Fire Code. Some additional properties which were not Life Hazard Uses, but which presented significant problems for fire suppression, or if destroyed by fire would result in an unusually high loss, were added to the list of target hazards. Target hazards included hospitals, a retreat house, high-rise buildings, large wooden residential buildings, schools, assisted-living and group home residences, a jail, houses of worship, senior citizen housing, a library, historic properties, and large apartment, office and commercial buildings.

Incident reports of the Morristown Fire Bureau were searched for the location of all structure fires from January 1, 1991 to August 1998. These locations were tabulated according to Ward and District.

Driving distances from Speedwell and from James to all 14 Ward/District centers, Ward/District extremes, and to all target hazards and structure fires were measured. Measurements were taken using Streets Plus, a computer mapping program from Microsoft Corporation (One Microsoft Way, Redmond, WA 98052). This program will measure distance in yards and in hundredths of a mile. Distances were measured using actual response routes.

Distances were tabulated in a spreadsheet and converted into time by the HUD/Rand formula:

$$T = 2.10 \sqrt{D} \quad \text{when D is less than or equal to 0.38 mile;}$$

$$\text{or:} \quad 0.65 + 1.70\,D \quad \text{when D is greater than or equal to 0.38 mile.}$$

Graphs were generated by the spreadsheets to enable visual comparison of the response times between James and Speedwell to centers, extremes, target hazards and past fires. For the Southeast side of town, tables and graphs were also prepared showing time saved and percent improvement by a firehouse at James.

Assumptions and Limitations

All distances were measured by the computer mapping program, Streets Plus. The accuracy of the program was checked with a rolling measure device from the Morristown Police Department (model MM45, by Rolatape, Spokane, Washington), and with careful use was found to be accurate within plus or minus 4%.

A further source of inaccuracy may be the distance-to-time conversion formula. The formula and the values of its constants have been validated and reported to show little variation over time and between locations, but there is certainly some small unknown level of inaccuracy.

Fire data from 1991 (when the incident data was computerized) until August 1998 was used. In order to compare 1998 data to other years, an extrapolation was performed to approximate fire data until December 31, 1998. Other limitations and sources of error include possible mistakes and omissions made in the NFIRS reports and possible mathematical errors in the collection and tabulation of data.

An assumption was made that the response characteristics of the four proposed sites for a new firehouse would be essentially identical to the South and James intersection, an approximate locus of the four proposed points. The 300 yard maximum distance between the sites and the representative intersection could result in a maximum of only 17.3 seconds difference in travel time in a response of over 0.38 miles. This discrepancy tends to cancel out, as gain in time in one direction equates with loss in another. The city of Fresno, California found that "Potential sites were identified as street intersections, and it was deemed acceptable to locate the site within one-quarter (1/4) mile linear distance from the intersection without distorting the travel time values appreciably" (1977).

Other assumptions were made in the identification of Target Hazards. Some locations clearly fit the definition of a Target Hazard; others depended on a judgment call of the author.

RESULTS

1. How are life safety and fire loss affected by response time?

The effects of response time were found to be well-documented in the literature. Fires can grow at an accelerating rate, so an increase in response time can equate to an exponentially larger fire, rescue problem and damage. Flashover and building collapse become more likely the longer suppression activities are delayed. A one-minute increase in response time has been found to be able to increase damage thousands of dollars.

2. Are there nationally recognized standards for response time?

The literature review was unable to locate any current nationally recognized standards for response time. Formerly (1972) the NFPA presented the criteria of having 90% of the responses receiving on scene condition reports within three minutes (first due), and the entire first due assignment on scene within five minutes, but this is not found in any of the current standards.

Different authors' and fire departments' goals for on scene time ranged from one and one-half to five minutes. The issue is clouded by differing definitions of response time. Several authors suggested that arrival before flashover is an important consideration. Flashover was found to be able to occur as soon as four minutes after flaming ignition.

Standards for response distance were found. The ISO requires a maximum distance of one and one-half miles for an engine and two and one-half miles for a truck company. Formerly (1976) the NFPA recommended that an engine be located within 2 miles in residential areas and one and one-half miles in commercial areas, but this standard has been dropped.

3. How have response times been affected by the closing of the Market Street firehouse and moving its companies to Speedwell Avenue?

Response times in the northern side of town (Speedwell's first due area) are unaffected and have remained the same.

Except for a very few locations in the immediate area of the firehouse, responses in the old first due district of Market Street may be divided into two groups: responses via Morris Street and responses via South Street. All responses via Morris Street will be increased by 0.38 minutes, equal to the distance between the Speedwell Avenue firehouse and the intersection of Spring and Morris Streets, through which both companies will travel. Similarly, all responses via South Street will be increased by 0.99 minutes (representing the distance from the Speedwell firehouse to South Street and South Park Place), except to locations on or near Mt. Kemble Avenue, which will remain about the same.

4. How would the building of a new firehouse on the southeast side of Morristown impact life response time, life safety, and fire loss?

The building of a new firehouse would shorten travel time (and therefore response time) on the southeast side of Morristown. Life safety would be improved and damage and loss reduced.

The Square-Root formula indicates that the average town-wide response distance, with only the Speedwell Avenue firehouse in service is:

$$0.6 \times \sqrt{2.9/1} = 1.02 \text{ miles town-wide average response distance}$$

This average response distance converted to travel time is:

$$0.65 + 1.7(1.02) = 2.38 \text{ minutes town-wide average travel time}$$

Using the formulas to include the new firehouse, we have:

$$0.6 \times \sqrt{2.9/2} = 0.72 \text{ miles average response distance, and:}$$

$$0.65 + 1.71(0.72) = 1.87 \text{ minutes average travel time}$$

If another firehouse were built, the town-wide average travel time would drop from 2.38 minutes to 1.87 minutes, realizing a 0.51 minute average time savings. This represents a 21% savings in travel time.

The literature expresses three dimensions in evaluating response and deployment: target hazards, fire history and equalized coverage.

Target Hazards

Target hazards were found to be distributed unequally around town. Figure 3 shows the number in each Ward/District:

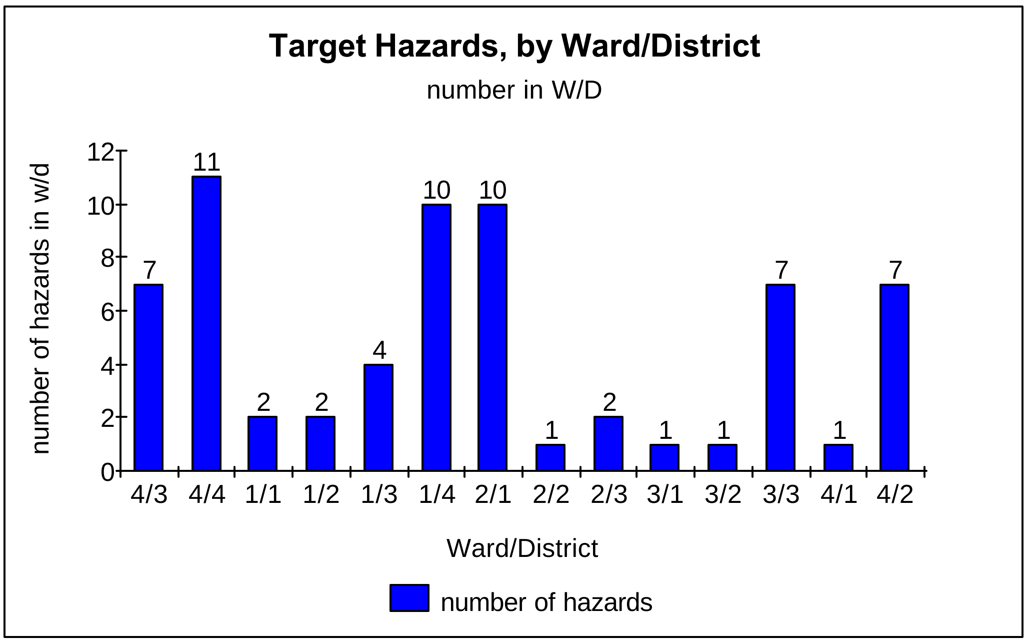


Figure 3

Response time to the target hazards in Speedwell's first due district would not be affected by the new firehouse at James. Response time to these special hazards would be decreased in the first and fourth wards.

Figure 4 shows the Ward/District average time saved and per cent improvement in travel time to these target hazards.

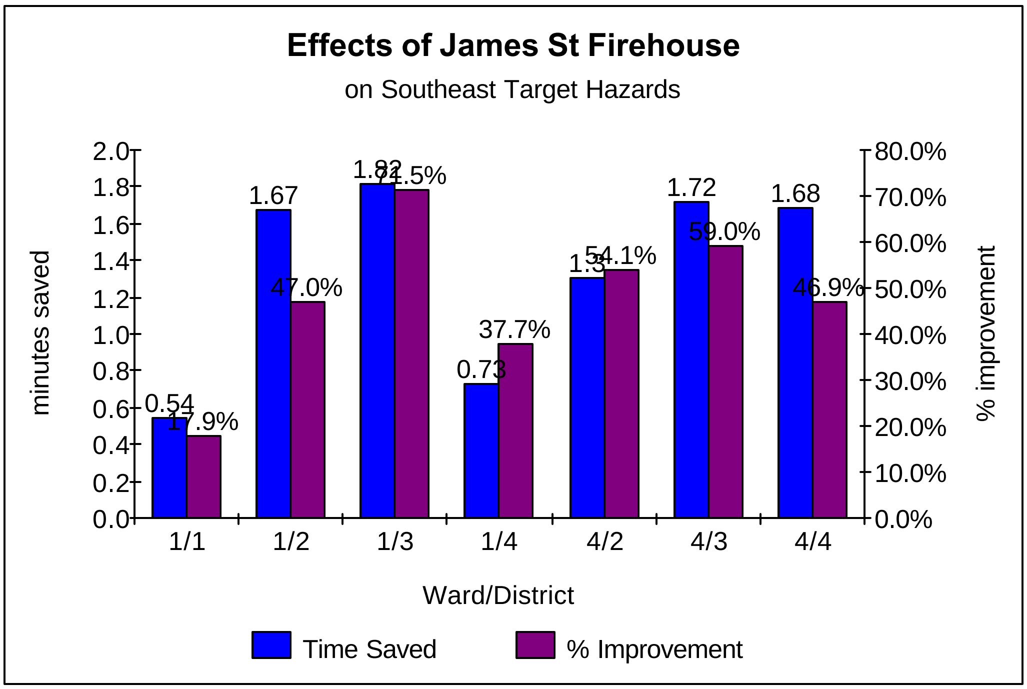


Figure 4

Risk

The second dimension of response time analysis is fire history. Also referred to as realized demand, fire history is a measure of risk. Like target hazards, structure fires are not distributed equally throughout Morristown. Figure 5 shows the distribution by Ward/District:

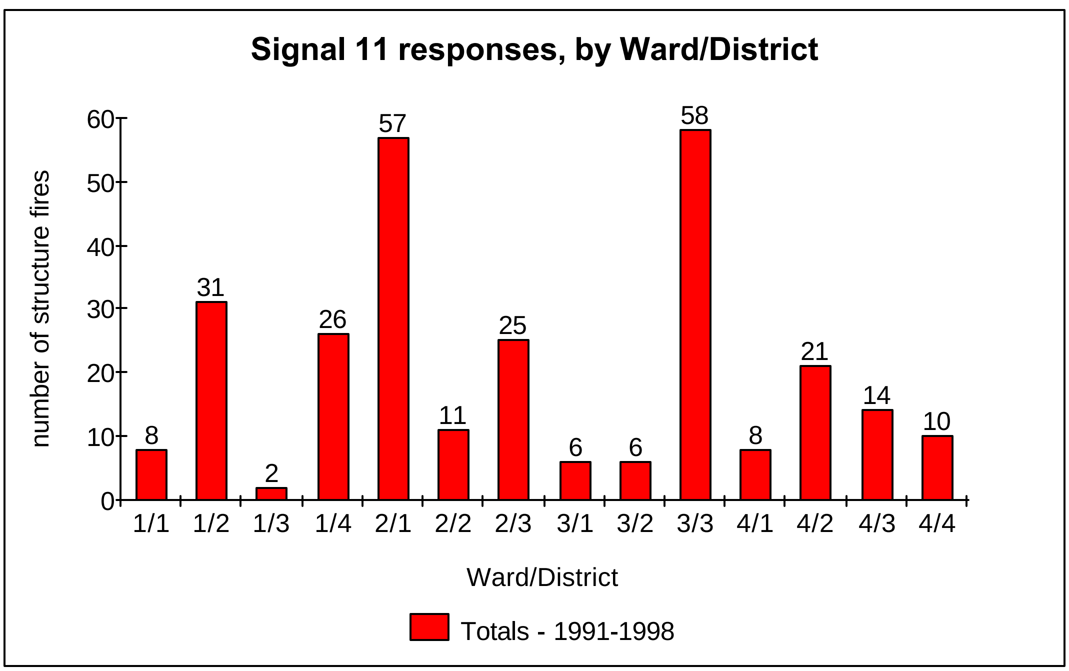


Figure 5

Figure 6 represents the trends of structure fires over time. The period of 1991-1993 was compared to 1996-1998 and the percentage increase or decrease was calculated:

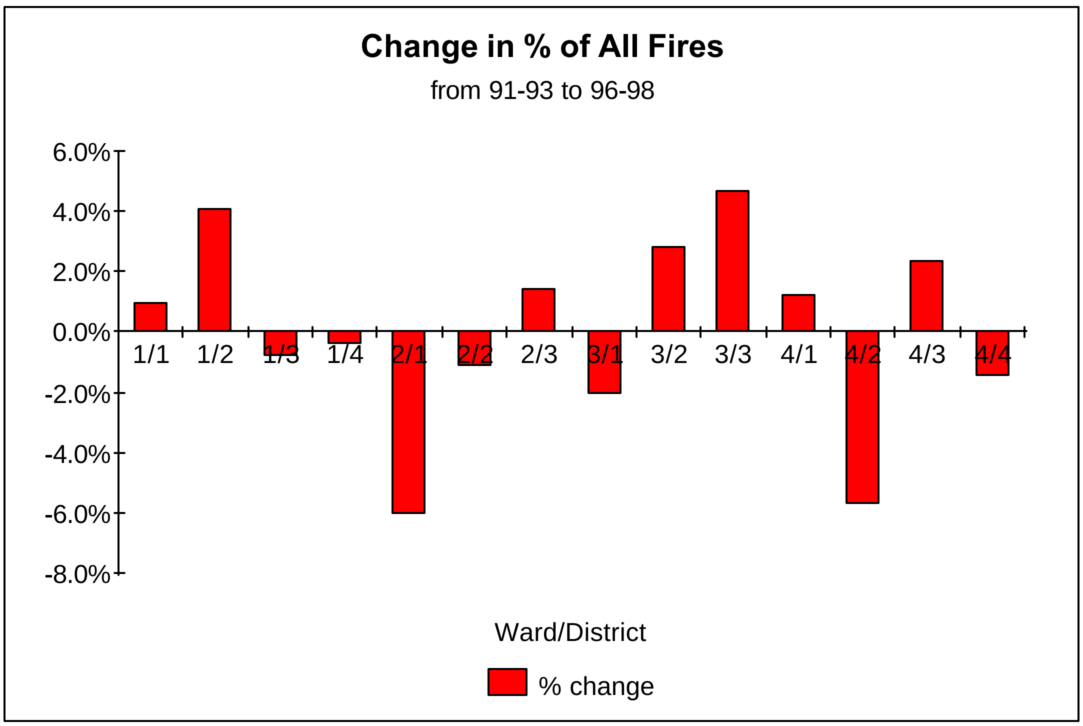


Figure 6

Fig 7 shows the effect of building a new firehouse near South and James Streets. The affected Ward/Districts are presented with time saved and per cent improvement.

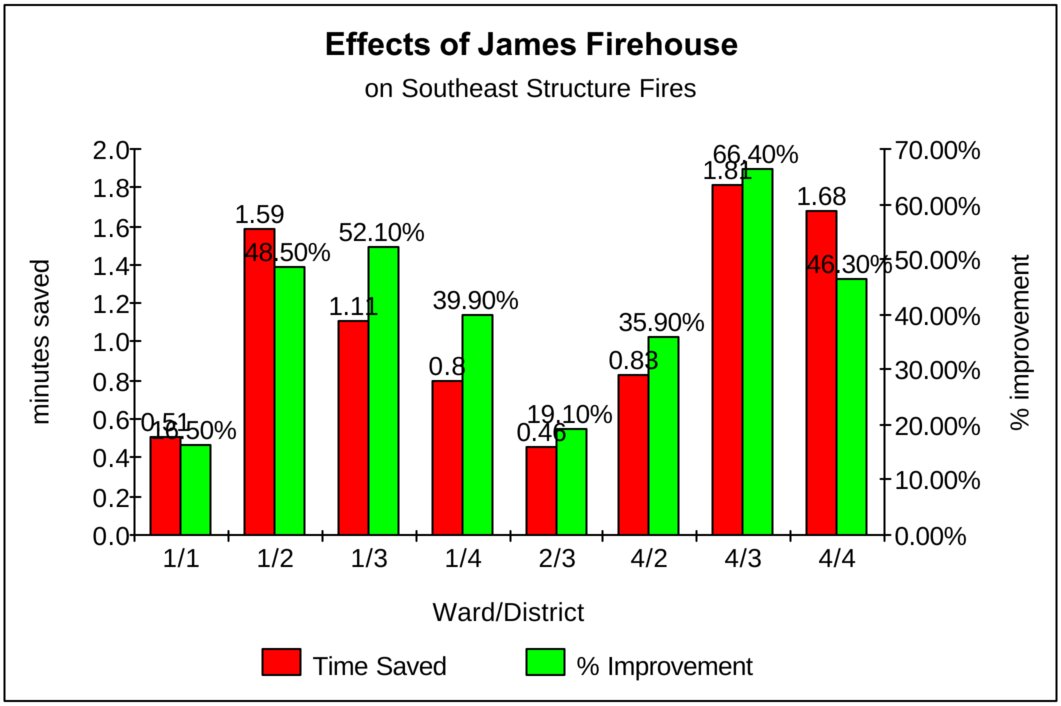


Figure 7

Equal Coverage

The third dimension of deployment analysis is equal coverage. Two measures of equality are presented: travel time to the Ward/District geographical center; and longest travel time from the existing Speedwell firehouse.

Figures7 and 8 show the response time from Speedwell and from James Street, to the geographic center of each Ward/District, and to the Extreme of each Ward/District.

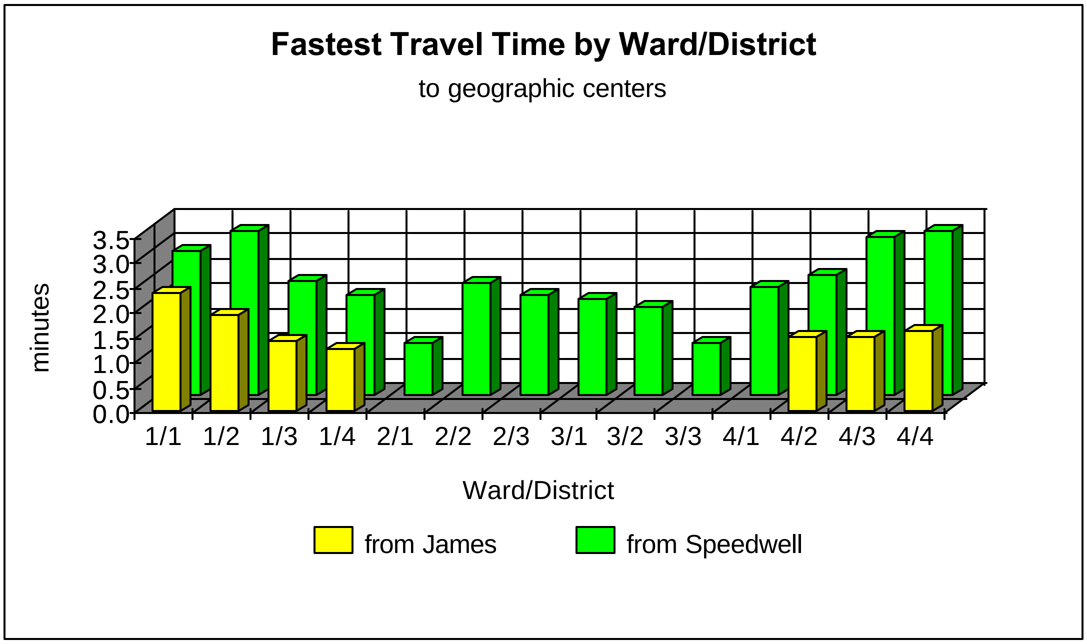


Figure 7

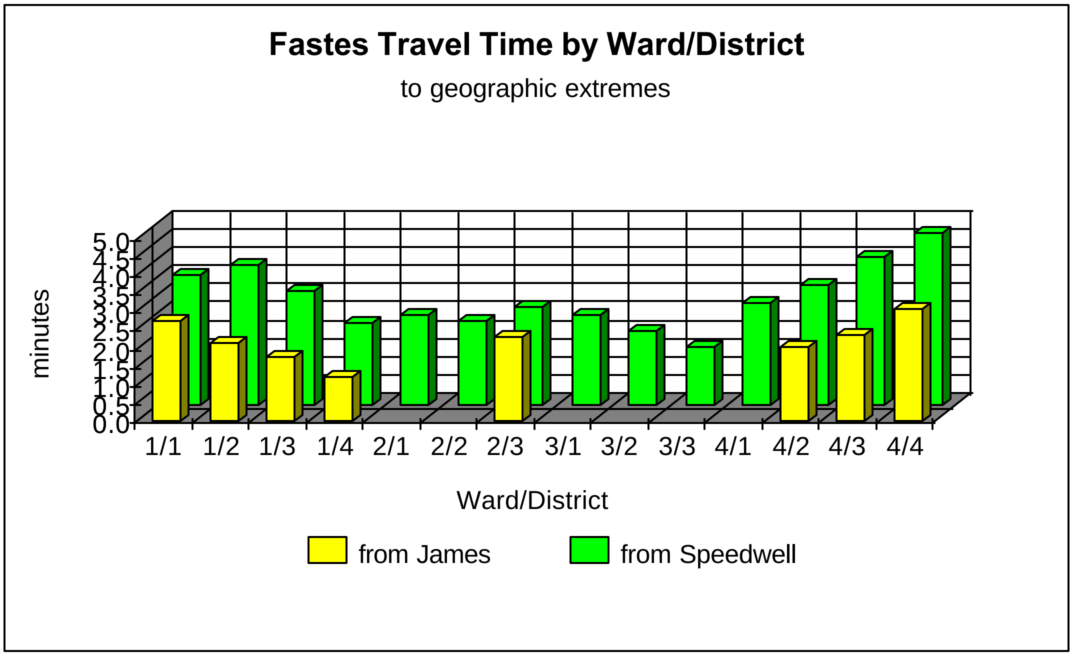

Fastes Travel Time by Ward/District
to geographic extremes
minutes
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1/1
1/2
1/3
1/4
2/1
2/2
2/3
3/1
3/2
3/3
4/1
4/2
4/3
4/4
Ward/District
from James
from Speedwell

Figure 8

The locations of target hazards and structure fires are not correlated closely, as shown in figure 9:

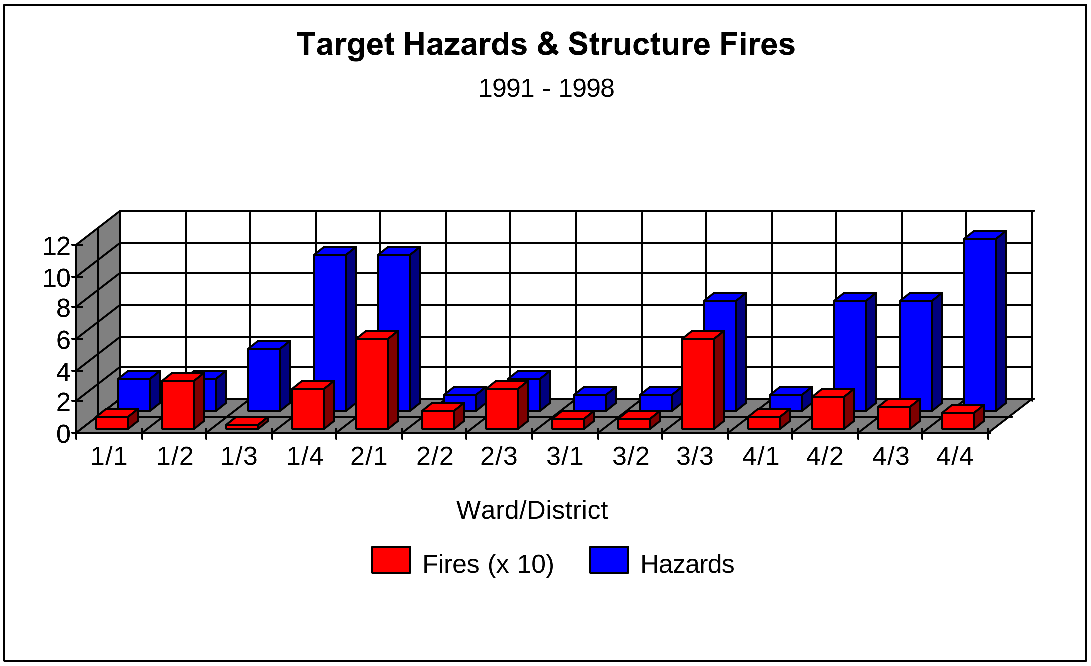


Figure 9

Finally, here is a chart showing structure fires, target hazards, and travel times from Speedwell and James to Ward/District Centers:

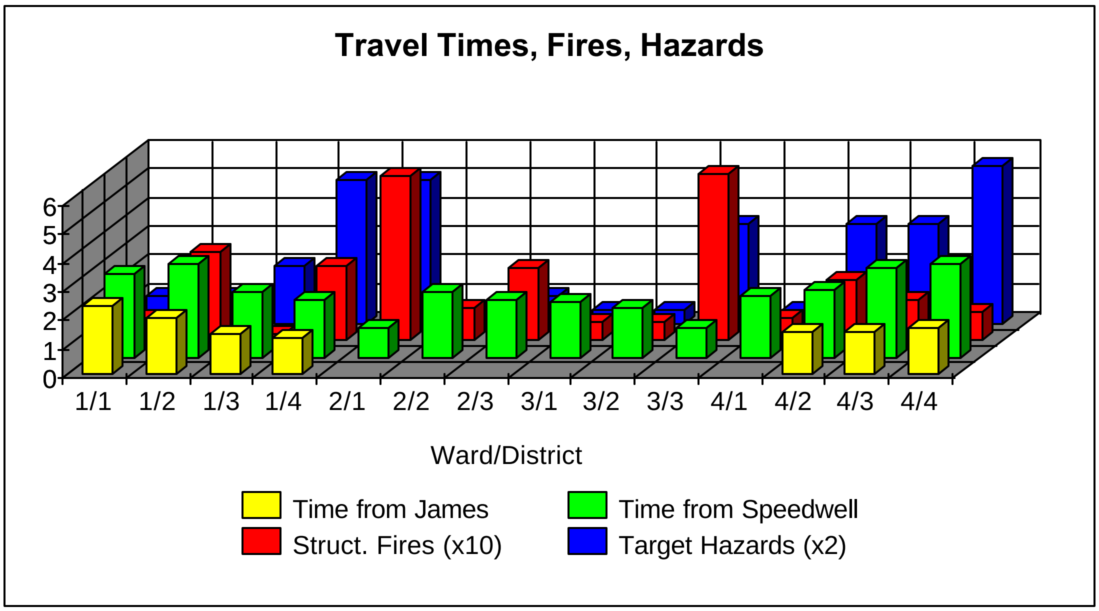


Figure 10

DISCUSSION

It is clear from the literature review that lower response times reap enhanced life safety and decreased losses from fire. Building a firehouse in the southeastern side of Morristown would achieve these goals. The question the town is struggling with is, How much will the town benefit from this amount of response time reduction, and is it enough to justify expending about

$1 million at the present time?

The improvements would be substantial. The travel time to target hazards in Ward/District 1/2 (which includes the central business district) would be improved by 37%. In W/D 1/2, which includes Morristown Memorial Hospital, the improvement in travel time would be 47%. Finally, response to W/D 4/4, which includes several large office buildings, would be 46% shorter.

The data on responses to past structure fires shows that 40.6% of all the town's structure fires occurred in W/D 2/1 and 3/3. The new firehouse would not impact on these areas at all. The present firehouse, Speedwell, is very well located on the border between these busy districts. The alternative of closing Speedwell after building one central firehouse in a more town-wide central location has also been discussed. This plan would move resources away from fires, increasing the average travel time and, presumably, average fire loss.

The 1/2 District is another focal point in allocation decisions. This district is dominated by Morristown Memorial Hospital, the town's largest employer. This property represents both high hazard and high risk—accounting for 24 of the town's 282 structures fires during the period studied. Building the new firehouse near James Street would provide a 50.2% improvement on travel time to the hospital.

Figure 6 shows which W/D's are more active or less active in recent years. W/D 2/1 (which has accounted for 20.1 % of all structure fires) appears to be slowing down, losing 6%

of its town-wide share in the 1996-1998 period compared to 1991-1993. District 3/3 (accounting for 20.5% of all structure fires), on the other hand, is becoming more active, up 4.7% in share since the early 90's. The hospital W/D, 1/2, is also growing, up 4% in share. This is a strong argument for providing coverage at both ends of the town.

The consideration of equal coverage is intuitive to any citizen who locates the Speedwell Avenue firehouse on a map. The present firehouse is approximately in the center of the northern half of town, with three-quarters of the town to its south and west. A measure of equal coverage is the range of travel times to the centers of the Ward/Districts. Responding only from Speedwell, the travel times to the W/D centers range from 3.30 minutes to 1.03 minutes, yielding a range of 2.27 minutes between wards that receive the fastest service to those receiving the slowest. The new James firehouse would yield quickest time in 1.03 minutes and slowest time to a W/D center of 2.37 minutes. This equals a range of only 1.34 minutes between the slowest and quickest. When examining the extreme distances (the farthest point in each W/D now traveled from Speedwell), there is even more difference in the ranges. Responding from Speedwell only, the range between the quickest and slowest service is 3.13 minutes; responding from the two firehouses, the range is 1.87 minutes difference.

In considering these statistics, a few words of caution are in order. Several measures in this study are expressed in averages, such as the current statistical average town-wide travel time of 2.38 minutes. An average means that many responses may be shorter and many may be longer than the average. For instance, if a fire department had 25 responses of one minute and five responses of seven minutes, the average response time is only two minutes, which seems good. However, the five seven-minute responses may be totally unacceptable.

Secondly, the response times generated by the HUD/Rand formula appear to be very optimistic for Morristown. The fire department is dispatched by the Police Department, and there is currently no ongoing record keeping of on-scene time. On the basis of a very limited number of spot checks of actual timed responses, the formula's constants, which represent a town's traffic and geographic characteristics, may need to be revised, producing somewhat longer actual times. The percentages of improvement, and comparison of times would remain the same; only the actual minute values would change.

If the town were to build the new firehouse, it would staffed by moving some of the personnel and apparatus from Speedwell rather than by hiring new personnel. This would have a detrimental effect of moving resources away from the highest risk W/D's: 2/1 and 3/3. In other words, to the extent that the first due travel time is reduced, the "last due" of the complete assignment would be increased. Responding from one location has the benefit of all companies arriving somewhat together, which facilitates teamwork and incident management. However, the benefit of having the first due on scene more quickly on responses to about half the districts is a good tradeoff. As Walker reports, interviewing a Deputy Chief in the Fire Department of New York:

> From a fire protection point of view, the first-engine (first-due engine) response time is usually more important than the second-engine response time...as far as this chief was concerned, the first-engine time should be weighed about twice as heavily as the second-engine time. (That is, getting the first engine to an incident 10 seconds sooner is worth about as much as getting the second there 20 seconds sooner.) (Walker, 1979, p. 83-84)

The Morristown, New Jersey Fire Bureau is a combination department, consisting of 29 career suppression personnel and about 20 active volunteer firefighters, maintaining a minimum on-duty staffing of a Captain and four firefighters. The on-duty crew brings the apparatus to the scene, while the volunteers are alerted by pager and respond directly to the scene in their own vehicles.

In addition to greater training demands, increased call volume has made it impossible for most volunteers to answer all (1200) calls. The general practice has been for most volunteers to respond only after the on-duty crew is on the scene, discovered a serious fire, and called for a general alarm. This procedure highlights the value of prompt on-scene arrival of the first unit, in order to make an assessment and call for a general alarm or mutual aid as early as possible.

RECOMMENDATIONS

It is the recommendation of this author that the town proceed with exploring the building of the new firehouse near South and James Streets. It is clear from this study that certain real benefits would result immediately, and probably even more in the future. Traffic will only increase, slowing response times further. The fire department will probably become involved with emergency medical services at some point in the future. Quick response will become even more important.

Further study is needed. The importance of good data cannot be overemphasized. "Without current data on response times...decisions to spend tax dollars on existing stations or to build new stations will be made from a purely speculative point of view" (Mason, 1996, p. 7). There is presently no mechanism or procedure in place to get response time measured by dispatch. The fire department should begin a program of self-timing responses, from wheel start to wheel stop, by vehicle drivers with a stopwatch. This data should then be used to validate the distance/time findings of this study, and modify the HUD/Rand formula as necessary.

The Morristown Ward and District lines were redrawn in 1991to reflect the 1990 census. Unfortunately, the Ward/District map in the captains' office was not changed until 1994, leading to errors in the incident reports. This necessitated checking the Ward and District of all the structure fires and target hazards used in this study, and it made impossible the use of all responses, since it was impractical to check the Ward/District locations of the over fifteen thousand total responses made since 1991. It is possible that other types of calls for service might have shown a different pattern than structure fires only. A careful three-month timed response study should shed some light. An attempt should be made to study emergency medical response patterns as well.

Finally, the Long-Range Firehouse-Needs Committee recommended contact with Morris Township to explore the possibility of some mutual cooperation efforts which could enhance response time. These efforts should be continued.

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Appendix A - Distance to Time Formula

distance/time formula -					
segment	distance D	2.1root D	.65 + 1.7D	if D = 0.38	travel time T
avg, 1 fire house	1.02	0	2.384	0	2.384
avg, 2 fire houses	0.72	0	1.874	0	1.874
Market to S. Park	0.077	0.5827264	0	0	0.58
Market to Spring & Morriw	0.26	1.0707941	0	0	1.07
Speedwell to South and park	0.539	0	1.5663	0	1.57
Speedwell to Spring and Morris	0.468	0	1.4456	0	1.45

Appendix B - Number of Target Hazards, by Ward/District

Ward/District	Number of Target Hazards
4/3	7
4/4	11
1/1	2
1/2	2
1/3	4
1/4	10
2/1	10
2/2	1
2/3	2
3/1	1
3/2	1
3/3	7
4/1	1
4/2	7
Totals	66

Appendix C - Time Saved to Target Hazards on the Southeastern Side

Target Hazards, time saved by James st firehouse						
Address	D from Speedw., miles	D from James, miles	T from Speedw., minutes	T from James, minutes	Time Saved, minutes	% Im-prove-ment
18 Altamont	0.92	0.29	2.21	1.13	1.08	48.9%
38 Dumont	0.57	0.42	1.62	1.36	0.26	15.8%
38 Headley	1.43	0.44	3.08	1.40	1.68	54.6%
James & Ogden	1.41	0.42	3.05	1.36	1.68	55.2%
63 Macculloch	0.99	0.37	2.33	1.28	1.06	45.2%
70 Macculloch	1.03	0.32	2.40	1.19	1.21	50.5%
91 Maple	1.05	0.15	2.44	0.81	1.62	66.6%
77 Madison	1.55	0.56	3.29	1.60	1.68	51.2%
100 Madison	1.55	0.58	3.29	1.64	1.65	50.2%
146 Madison	1.88	0.89	3.85	2.16	1.68	43.8%
1 Miller Rd	0.79	0.21	1.99	0.96	1.03	51.7%
40 Overlook	1.49	0.73	3.18	1.89	1.29	40.6%
36 South	0.61	0.37	1.69	1.28	0.41	24.3%
44 South	0.64	0.34	1.74	1.22	0.51	29.5%
65 South	0.69	0.29	1.82	1.13	0.69	38.0%
100 South	0.75	0.23	1.93	1.01	0.92	47.7%
125 South	0.83	0.14	2.06	0.79	1.28	61.9%
247 South	1.33	0.34	2.91	1.22	1.69	57.9%
270 South	1.33	0.34	2.91	1.22	1.69	57.9%
77 W Valley View	1.70	1.37	3.54	2.98	0.56	15.8%
55 Madison	1.45	0.46	3.12	1.43	1.68	54.0%
65 Madison	1.53	0.54	3.25	1.57	1.68	51.8%
95 Madison	1.61	0.62	3.39	1.70	1.68	49.7%

Appendix C continued

101 Madison	1.64	0.65	3.44	1.76	1.68	49.0%
111 Madison	1.75	0.76	3.63	1.94	1.68	46.4%
131 Madison	1.85	0.86	3.80	2.11	1.68	44.3%
151 Madison	1.90	0.91	3.88	2.20	1.68	43.4%
161 Madison	1.95	0.96	3.97	2.28	1.68	42.4%
163 Madison	1.95	0.96	3.97	2.28	1.68	42.4%
177 Madison	2.03	1.04	4.10	2.42	1.68	41.0%
230 Morris	1.12	0.82	2.55	2.04	0.51	20.0%
50 So Park Pl	0.58	0.51	1.64	1.52	0.12	7.3%
200 South	1.00	0.03	2.35	0.36	1.99	84.5%
110 South	0.78	0.20	1.98	0.94	1.04	52.5%
161 James	1.73	0.74	3.59	1.91	1.68	46.9%
181 South	0.99	0.00	2.33	0.00	2.33	100.0%
2 Hamilton	1.14	0.15	2.59	0.81	1.77	68.6%
7 Hamilton	1.14	0.15	2.59	0.81	1.77	68.6%
10 Madison	1.20	0.21	2.69	0.96	1.73	64.2%
AVERAGES:	1.28	0.50	2.82	1.45	1.37	48.3%

Appendix D - Time Saved and % Improvement to Southeast Target Hazards

Southeast time saved & % imporvement--hazards						
				GRAPH:		
W/D	Time Saved	% Improvemer		Ward/D	Time S	% Improveme
1/1	0.56	15.8%		1/1	0.54	17.9%
1/1	0.51	20.0%		1/2	1.67	47.0%
avgs:	0.54	17.9%		1/3	1.82	71.5%
				1/4	0.73	37.7%
1/2	1.65	50.2%		4/2	1.3	54.1%
1/2	1.68	43.8%		4/3	1.72	59.0%
avgs:	1.67	47.0%		4/4	1.68	46.9%
1/3	1.99	84.5%				
1/3	1.77	68.6%				
1/3	1.77	68.6%				
1/3	1.73	64.2%				
avgs:	1.82	71.5%				
1/4	1.08	48.9%				
1/4	0.26	15.8%				
1/4	1.03	51.7%				
1/4	0.41	24.3%				
1/4	0.51	29.5%				
1/4	0.69	38.0%				
1/4	0.92	47.7%				
1/4	1.28	61.9%				
1/4	0.12	7.3%				
1/4	1.04	52.5%				
avgs:	0.73	37.7%				

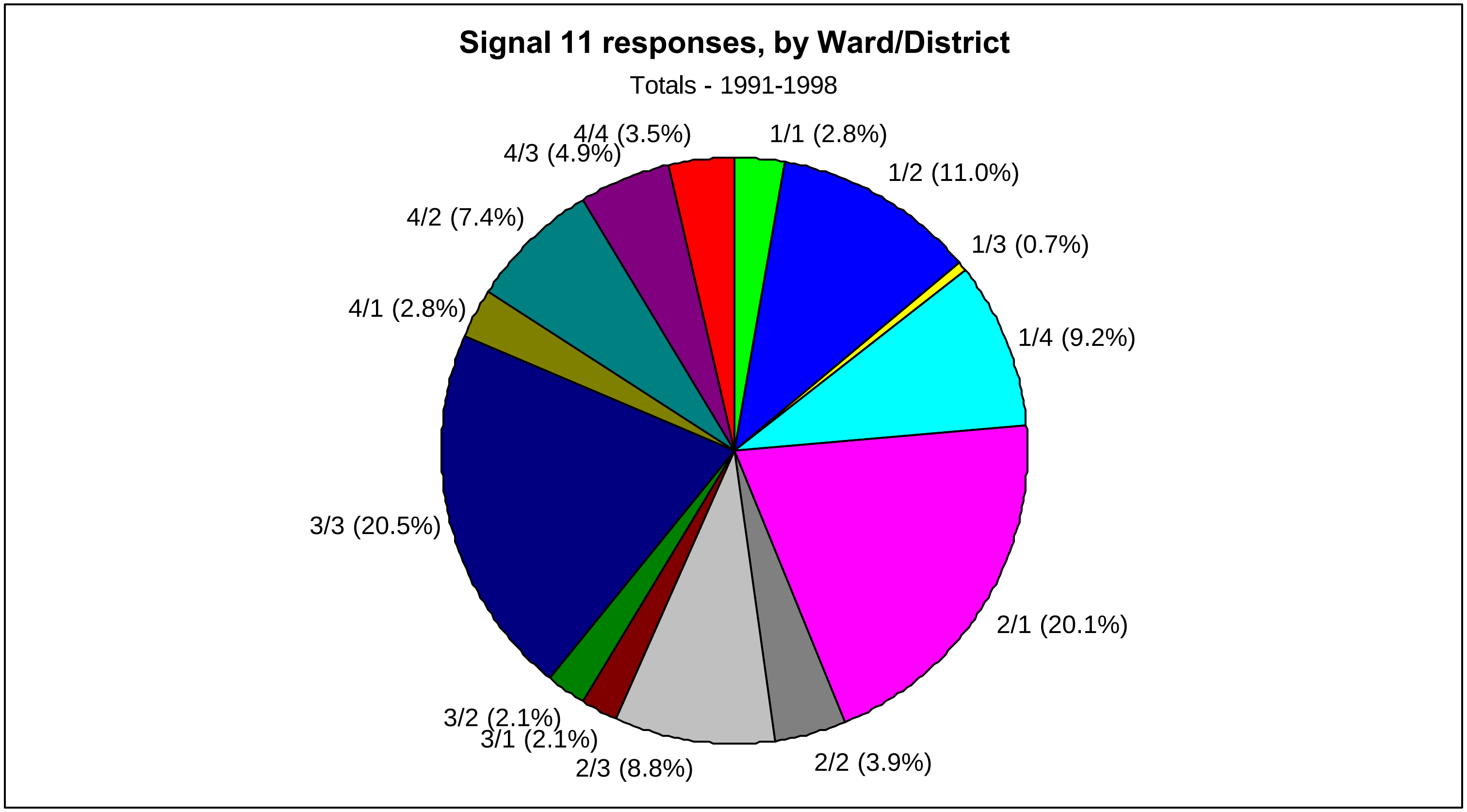
Appendix D continued

4/2	1.06	45.2%				
4/2	1.21	50.5%				
4/2	1.62	66.6%				
avgs:	1.30	54.1%				
4/3	1.68	54.6%				
4/3	1.68	55.2%				
4/3	1.29	40.6%				
4/3	1.69	57.9%				
4/3	1.69	57.9%				
4/3	1.68	46.9%				
4/3	2.33	100.0%				
avgs:	1.72	59.0%				
4/4	1.68	51.2%				
4/4	1.68	54.0%				
4/4	1.68	51.8%				
4/4	1.68	49.7%				
4/4	1.68	49.0%				
4/4	1.68	46.4%				
4/4	1.68	44.3%				
4/4	1.68	43.4%				
4/4	1.68	42.4%				
4/4	1.68	42.4%				
4/4	1.68	41.0%				
avgs:	1.68	46.9%				

Appendix E - Number of Structure Fires by Ward/District

Ward/District	Number of S
Ward/District	Totals - 199
1/1	8
1/2	31
1/3	2
1/4	26
2/1	57
2/2	11
2/3	25
3/1	6
3/2	6
3/3	58
4/1	8
4/2	21
4/3	14
4/4	10
TOTALS	282

Appendix F - Structure Fires by Ward/District



Appendix G - Time Saved on Southeast Side to Structure

Signal 11's, time saved by James St firehouse						
Address	D from Speedw., miles	D from James, miles	T from Speedw., minutes	T from James, minutes	Time Saved, minutes	% Im-prove-ment
1998						
19 Malcolm	1.83	1.50	3.76	3.20	0.56	14.9%
4 windmill	1.85	0.86	3.80	2.11	1.68	44.3%
100 Madison Av	1.55	0.58	3.29	1.64	1.65	50.2%
100 Madison Av	1.55	0.58	3.29	1.64	1.65	50.2%
100 Madison Av	1.55	0.58	3.29	1.64	1.65	50.2%
100 Madison Av	1.55	0.58	3.29	1.64	1.65	50.2%
119 Morris St	0.60	0.49	1.67	1.48	0.19	11.2%
60 Elm	0.75	0.31	1.93	1.17	0.76	39.3%
181 South	0.99	0.00	2.33	0.00	2.33	100.0%
1997						
17 Malcolm	1.83	1.50	3.76	3.20	0.56	14.9%
1 Washington Pl	1.18	0.85	2.66	2.10	0.56	21.1%
100 Madison	1.55	0.58	3.29	1.64	1.65	50.2%
100 Madison	1.55	0.58	3.29	1.64	1.65	50.2%
7 Elm	0.90	0.06	2.18	0.51	1.67	76.4%
100 Madison	1.55	0.58	3.29	1.64	1.65	50.2%
74 Ridgedale	0.98	0.76	2.32	1.94	0.37	16.1%
1996						
103 Ridgedale	1.18	0.97	2.66	2.30	0.36	13.4%
100 Madison	1.55	0.58	3.29	1.64	1.65	50.2%
100 Madison	1.55	0.58	3.29	1.64	1.65	50.2%
100 Madison	1.55	0.58	3.29	1.64	1.65	50.2%
100 Madison	1.55	0.58	3.29	1.64	1.65	50.2%
17-19 Pine St	0.74	0.36	1.91	1.26	0.65	34.0%
41 Elm	0.80	0.26	2.01	1.07	0.94	46.7%
45 Pine	0.60	0.48	1.67	1.47	0.20	12.2%
53 Maple	0.87	0.33	2.13	1.21	0.92	43.3%
82 Maple	0.96	0.23	2.28	1.01	1.27	55.9%
3 Robertson	1.98	0.99	4.02	2.33	1.68	41.9%
8 Knollwood	1.21	0.22	2.71	0.98	1.72	63.6%
10 Dorado	2.10	1.11	4.22	2.54	1.68	39.9%
163 Madison	1.96	0.97	3.98	2.30	1.68	42.3%
9 Dorado	2.14	1.15	4.29	2.61	1.68	39.2%

Fires

Appendix G - Continued

1995						
80 W Valley View	1.48	1.16	3.17	2.62	0.54	17.2%
100 Franklin	1.38	0.59	3.00	1.65	1.34	44.8%
64 Maple	0.89	0.30	2.16	1.15	1.01	46.8%
100 Madison	1.55	0.58	3.29	1.64	1.65	50.2%
2 John Glen	1.46	1.13	3.13	2.57	0.56	17.9%
45 Olyphant Dr	1.04	0.75	2.42	1.93	0.49	20.4%
74 1/2 Ridgedale	0.98	0.75	2.32	1.93	0.39	16.9%
35 Ridgedale	1.04	0.63	2.42	1.72	0.70	28.8%
95 Mt Kemble	1.11	1.09	2.54	2.50	0.03	1.3%
10 Perry	1.03	0.24	2.40	1.03	1.37	57.2%
16 Perry	1.05	0.26	2.44	1.07	1.36	56.0%
48 Mt Kemble	0.84	0.84	2.08	2.08	0.00	0.0%
41 James	1.18	0.19	2.66	0.92	1.74	65.5%
6 Crestwood	1.17	0.18	2.64	0.89	1.75	66.2%
270 South	1.33	0.34	2.91	1.22	1.69	57.9%
77 Madison	1.55	0.56	3.29	1.60	1.68	51.2%
1994						
100 Madison	1.55	0.58	3.29	1.64	1.65	50.2%
7 Randolph	1.27	0.90	2.81	2.18	0.63	22.4%
176 South	0.91	0.06	2.20	0.51	1.68	76.6%
45 Elm	0.80	0.26	2.01	1.07	0.94	46.7%
30 Elm	0.87	0.19	2.13	0.92	1.21	57.0%
100 Madison	1.55	0.58	3.29	1.64	1.65	50.2%
3 Ridgedale	0.81	0.49	2.03	1.48	0.54	26.8%
30 Lafayette	1.20	0.70	2.69	1.84	0.85	31.6%
72 Abbett	0.83	0.83	2.06	2.06	0.00	0.0%
55 Maple	0.87	0.34	2.13	1.22	0.90	42.5%
73 Maple	0.92	0.25	2.21	1.05	1.16	52.6%
237 South	1.25	0.26	2.78	1.07	1.70	61.4%
40 Overlook	1.54	0.79	3.27	1.99	1.28	39.0%
40 Colles	0.99	0.53	2.33	1.55	0.78	33.5%

Appendix G - Continued

1993						
25 Washington Av	1.14	0.87	2.59	2.13	0.46	17.7%
51 Washington Av	1.24	0.98	2.76	2.32	0.44	16.0%
100 Madison	1.55	0.58	3.29	1.64	1.65	50.2%
100 Madison	1.55	0.58	3.29	1.64	1.65	50.2%
100 Madison	1.55	0.58	3.29	1.64	1.65	50.2%
100 Madison	1.55	0.58	3.29	1.64	1.65	50.2%
100 Madison	1.55	0.58	3.29	1.64	1.65	50.2%
96-98 Elm	0.67	0.42	1.79	1.36	0.43	23.8%
31 Altamont	0.95	0.32	2.27	1.19	1.08	47.6%
8 Dehart	0.64	0.40	1.74	1.33	0.41	23.5%
58 Ridgedale	0.95	0.71	2.27	1.86	0.41	18.0%
29 Wetmore	0.94	0.73	2.25	1.89	0.36	15.9%
71 Wetmore	1.17	0.94	2.64	2.25	0.39	14.8%
3 Maple	0.80	0.56	2.01	1.60	0.41	20.3%
15 James	1.07	0.08	2.47	0.59	1.88	75.9%
1992						
100 Madison	1.55	0.58	3.29	1.64	1.65	50.2%
100 Madison	1.55	0.58	3.29	1.64	1.65	50.2%
34 King st	0.78	0.44	1.98	1.40	0.58	29.3%
35 South	0.63	0.33	1.72	1.21	0.51	29.9%
55 Elm	0.75	0.31	1.93	1.17	0.76	39.3%
56 Elm	0.77	0.30	1.96	1.15	0.81	41.3%
86 South	0.70	0.28	1.84	1.11	0.73	39.6%
86 South	0.70	0.28	1.84	1.11	0.73	39.6%
162 South	0.90	0.09	2.18	0.63	1.55	71.1%
50 Elm	0.78	0.29	1.98	1.13	0.85	42.8%
191 South	1.07	0.08	2.47	0.59	1.88	75.9%
12 Dorado	2.03	1.04	4.10	2.42	1.68	41.0%
77 Madison	1.55	0.56	3.29	1.60	1.68	51.2%
77 Madison	1.55	0.56	3.29	1.60	1.68	51.2%
181 South	0.99	0.00	2.33	0.00	2.33	100.0%
77 Madison	1.55	0.56	3.29	1.60	1.68	51.2%

Appendix G - Continued

1991						
77 W Valley View	1.68	1.43	3.51	3.08	0.43	12.1%
100 Madison	1.55	0.58	3.29	1.64	1.65	50.2%
100 Madison	1.55	0.58	3.29	1.64	1.65	50.2%
100 Madison	1.55	0.58	3.29	1.64	1.65	50.2%
19 Randolph	1.70	0.94	3.54	2.25	1.29	36.5%
171 Morris st	0.78	0.46	1.98	1.43	0.54	27.5%
24 Altamont	0.93	0.30	2.23	1.15	1.08	48.4%
91 Elm	0.70	0.36	1.84	1.26	0.58	31.5%
37 Wetmore	0.98	0.74	2.32	1.91	0.41	17.6%
5 Wetmore	0.85	0.61	2.10	1.69	0.41	19.5%
66 Wetmore	1.13	0.88	2.57	2.15	0.43	16.5%
91 Macculloch	1.10	0.27	2.52	1.09	1.43	56.7%
203 South	1.11	0.12	2.54	0.73	1.81	71.3%
131 Madison	1.83	0.84	3.76	2.08	1.68	44.7%
320 South	1.56	0.57	3.30	1.62	1.68	51.0%
AVERAGES:	1.23	0.57	2.73	1.58	1.15	41.3%

Appendix H - Time Saved and % Improvement to Structure Fires, by Ward/District

Graph: SE side of town: itme saved & % improved				
Ward/Distri	Time Saved	% Improvement		
1/1	0.51	16.50%		
1/2	1.59	48.50%		
1/3	1.11	52.10%		
1/4	0.8	39.90%		
2/3	0.46	19.10%		
4/2	0.83	35.90%		
4/3	1.81	66.40%		
4/4	1.68	46.30%		

Appendix I - Trends of Structure Fires, by Ward/District

History-sig 11 trends						
W/D	Sig 11 91-93	as % of all fires	sig 11 96-98	as % of all fires	% change of portion of a	
1/1	3	2.4%	3	3.3%	0.9%	
1/2	13	10.2%	13	14.3%	4.0%	
1/3	1	0.8%	0	0.0%	-0.8%	
1/4	13	10.2%	9	9.9%	-0.3%	
2/1	30	23.6%	16	17.6%	-6.0%	
2/2	7	5.5%	4	4.4%	-1.1%	
2/3	8	6.3%	7	7.7%	1.4%	
3/1	4	3.1%	1	1.1%	-2.1%	
3/2	2	1.6%	4	4.4%	2.8%	
3/3	22	17.3%	20	22.0%	4.7%	
4/1	4	3.1%	4	4.4%	1.2%	
4/2	10	7.9%	2	2.2%	-5.7%	
4/3	4	3.1%	5	5.5%	2.3%	
4/4	6	4.7%	3	3.3%	-1.4%	
	127		91			

Appendix J - Ward/District Centers, Time Saved

	WARD / DISTRICT CENTERS, Time Saved by James St. Firehouse					
		D from	D from	T from	T from	Time
Ward/	Address	Speedw.	James,	Speedw	James,	Saved,
Dist		miles	miles	minutes	minutes	minutes
1/1	Morris Av & Georgian Rd	1.33	1.01	2.91	2.37	0.54
1/2	Franklin St & De Kalb Pl	1.56	0.76	3.30	1.94	1.36
1/3	Franklin St & Ford Av	0.96	0.44	2.28	1.40	0.88
1/4	Pine ST & King Pl	0.80	0.35	2.01	1.24	0.77
4/2	Miller Rd & Colles Av	1.03	0.49	2.40	1.48	0.92
4/3	Lidgerwood& Edgewood	1.48	0.49	3.17	1.48	1.68
4/4	Parsons Village, Bldg 13	1.55	0.56	3.29	1.60	1.68
	AVERAGES:	1.24	0.59	2.77	1.65	1.12
Wards/Districts Not Affected:						
		D from	D from	T from	T from	
Ward/	Address	Speedw.	James,	Speedw	James,	
Dist		miles	miles	minutes	minutes	
2/1	Logan Pl & Pocahontas St	0.25	1.28	1.05	2.83	
2/2	Hilliary Av @ bend	0.95	1.61	2.27	3.39	
2/3	Abbett Av & Jardine Rd	0.80	0.87	2.01	2.13	
3/1	Ralph Pl & Willard Pl	0.75	1.79	1.93	3.69	
3/2	Kenmuir Av & Milton Pl	0.65	1.59	1.76	3.35	
3/3	Early St & Atno Av	0.24	1.14	1.03	2.59	

Appendix K - Ward/District Extremes, Time Saved

	WARD / DISTRICT EXTREMES,Time Saved by James St. Firehouse					
Ward/ Dist	Address	D from Speedw., miles	D from James, miles	T from Speedw. minutes	T from James, minutes	Time Saved, minutes
1/1	Washington Av & Oak La	1.72	1.22	3.57	2.72	0.85
1/2	Franklin St & Madison Av	1.88	0.89	3.85	2.16	1.68
1/3	Revere Rd, end	1.47	0.64	3.15	1.74	1.41
1/4	Altamont Ct, end	0.95	0.32	2.27	1.19	1.08
2/3	Ridgedale Av & John St	1.19	0.97	2.67	2.30	0.37
4/2	Overlook Rd @ border	1.56	0.80	3.30	2.01	1.29
4/3	Windmill Dr & Robertson	2.00	1.01	4.05	2.37	1.68
4/4	Dorado, near Degan	2.41	1.42	4.75	3.06	1.68
	AVERAGES:	1.65	0.91	3.45	2.19	1.26
Wards/Districts Not Affected:						
Ward/ Dist	Address	D from Speedw., miles	D from James, miles	T from Speedw. minutes	T from James, minutes	
2/1	Speedwell Av, @ border	1.08	2.11	2.49	4.24	
2/2	Cory Rd & Gregory Ter	0.99	1.81	2.33	3.73	
3/1	Lake Rd @ border	1.07	2.10	2.47	4.22	